Title	The effects of introducing stroke sequences on the writing of Chinese characters in primary-one students of Hong Kong
Other Contributor(s)	University of Hong Kong
Author(s)	Cheng, Kwok-ying, Elaine
Citation	
Issued Date	2005
URL	http://hdl.handle.net/10722/56210
Rights	Creative Commons: Attribution 3.0 Hong Kong License

The effect of introducing stroke sequences on the writing of Chinese characters in primary-one students of Hong Kong

Cheng Kwok Ying, Elaine

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, April 30, 2005.

The effect of introducing stroke sequences on the writing of Chinese characters in primary-one students of Hong Kong

Cheng Kwok Ying, Elaine

Abstract

There has been a myth that introducing stroke sequence would aid the writing of characters. If the myth is true, the implication is that the introducing of stroke sequence should have a positive effect on writing. Since there exists more than one stroke sequence, consistency of the stroke sequence introduced may also affect the influence of stroke sequence on writing. The myth was verified with a delay copying task where pseudo-characters were presented with or without stroke sequence. The consistency effect was verified with a delay copying task where pseudo-characters were presented with consistent or inconsistent stroke sequences. Results indicated that there was no effect from the introduction of stroke sequence or the consistency of stroke sequence on writing accuracy, but the consistency of stroke sequence affected the stroke sequence being used in writing the characters.

Introduction

There is a myth claiming that stroke sequence learning is important to the writing of Chinese characters. Some pre-primary settings and parents emphasize on the importance of the use of the conventional stroke sequence. Both teachers and parents would introduce stroke sequence in writing characters and give supervision on writing characters. The stroke sequence introduced in school and at home might not be the same, and therefore inconsistent stroke sequence is received. The effect of introducing stroke sequence and the effect of the consistency of the stroke sequence introduced are worth investigating. To investigate the myth, one has to know more about stroke, stroke sequence of Chinese character and logographeme before going into the analysis of Chinese orthography.

A stroke is defined as a line made between touching and leaving the paper with pen (Law, & Leung, 2000). There are eight basic stroke types which are distinguished from the traditional Chinese calligraphy of the modern script (Kai Shu), namely a dot, a horizontal stroke, a vertical stroke, an angled stroke, a downward stroke going to the left, a downward stroke going to the right, an upward stroke going to the right, and a hook (Wang, 1973). Different strokes combine to form different characters. For example, a horizontal stroke, a downward stroke going to the left, a vertical stroke and a dot combine to form the character 不 (meaning no, /p□t_5/) and a downward stroke going to the left, two horizontal strokes and a hook combine to form the character 手

(meaning hand, /s□u_{35}/). The relative position of the strokes is also important as a change of spatial arrangement would result in a totally different character. For example, the part 木 and the part 口 in the character 杏 (meaning apricot, /h□ŋ22/) and the character 呆 (meaning dull, /□i_{21}/) are upside-down.

In writing a character which has more than one stroke, each stroke is written one after the other. The order in which the strokes are being written is called stroke sequence. The precise shape of the strokes, the direction along which the strokes should be written and the conventional stroke sequences are governed by some general stroke sequence rules (Appendix A) followed by those who practiced Chinese calligraphy (Fei, 1992; Law, Ki, Chung, Ko, & Lam, 1998). The conventional stroke sequence was developed gradually through the consideration of writing speed, aesthetics, and smoothness in writing since ancient time. Occasionally, there are more than one possible stroke sequence based on the stroke sequence rules. For example, the character 皮 could be written stroke by stroke from , , , to according to the rule of writing from top to bottom; from , , , to according to the rule of writing from left to right; or from , , , to according to the rules of writing from top to bottom and writing a horizontal stroke before a vertical stroke. The possible stroke sequence other than the conventional one is termed non-conventional stroke sequence.

Logographemes were identified as the basic unit of the Chinese writing system by Law et al.

(2000). Logographemes are identified based on the three major rules: (1) spatial separation of components, (2) replaceability of components and (3) co-occurrence. For example, the character 鬧 could be broken into give five logographemes based on the above rules, namely 門, , , 十, 口. It is obvious that some logographemes carry phonological information. From the previous example, the logographeme 門, when it acts as an isolated character, is pronounced as /mun_{21}/ meaning door while there is no phonological information for the logographeme .

There were three studies about stroke sequence in Chinese characters (Flores d' Arcais, 1994; Law et al., 1998, Yim-Ng, Varley, & Andrade, 2000). The studies carried out by Flores d' Arcais (1994) and Yim-Ng et al. (2000) were about the effect of stroke sequence on Chinese character recognition and Law et al.'s study was about the stroke sequence errors in writing Chinese characters. However, there was no study addressing the effect of introducing stroke sequence on writing and the effect of the consistency of the introduced stroke sequence.

Law et al. (1998) investigated children's stroke sequence errors in writing Chinese characters. A total of 72 primary-one students in Hong Kong were invited to do direct copy on ten Chinese characters with different familiarity. The conventional stroke sequence of each character was not given before the direct copying. The accuracy and the stroke sequence used in writing the characters were analyzed. The results showed that the accuracy in copying familiar characters in primary-one students was good (98% accuracy). When stroke sequence was considered in the

judgment of correctness, the performance was much poorer (34% accuracy). Student was able to write characters correctly in stroke sequence other than the conventional one. It appeared that the accuracy in copying Chinese characters was not closely related to the use of the conventional stroke sequence. A detail look into the study revealed that the stimuli in the study were not controlled stringently. The character familiarity was controlled and the characters were categorized into three groups (familiar, unfamiliar with familiar components and unfamiliar with unfamiliar components), but there was no control over the number of stimuli in each group (four in familiar group, four in unfamiliar group with familiar components and two in unfamiliar with unfamiliar components), the number of strokes in each characters (mean: 10.8 in familiar group, 12.5 in unfamiliar group with familiar components and 13.0 in unfamiliar group with unfamiliar components) and the number of logographemes in each character. Since the number of strokes and the number of logographemes in a character have already been proven to be factors affecting reading and writing, a lack of control over those factors may confound the study. The study did not address directly about the effect of introducing stroke sequence on character writing because the data was collected through direct copying without explicit introduction of stroke sequence. The provision of Chinese characters for direct copying only stimulated the writing of characters in the subjects' preferred stroke sequence which might or might be identical to the conventional stroke sequence.

In Yim-Ng et al.'s (2000) study, 20 males aged between 60 and 75 years without neurological impairment, 20 males aged 25-38 years and 20 females aged 25-40 years were recruited to recognize Chinese characters. The study investigated the effect of finger tracing on the recognition of Chinese characters. Subjects were blindfolded and their fingers were passively moved in either one of the three conditions: 1) along the conventional stroke sequence, 2) along the stroke sequence without spatial configuration (every stroke was started at the centre of the grid) and 3) along the stroke sequence without specific stroke sequence (the stroke sequence was randomized). The stimuli were controlled on the number of characters in each condition and the number of strokes (three to six strokes) in each characters. Results indicated that subjects performed significantly poorer when there was no spatial configuration or no specific stroke sequence. It suggested that the spatial arrangement of strokes and the specific stroke sequence would affect the naming of characters. The authors satisfied with the explanation that visuo-spatial representation was evoked by the finger tracing and therefore it was important to have stroke sequence and spatial information of strokes for visuo-spatial encoding. However, the blindfolded situation is rare in the naturalistic environment and people seldom use only the information from finger tracing in character recognition. Although it was reflected that stroke sequence would affect character recognition, it does not address directly its effect on writing. It is common to encounter situations where we could recognize a written word but could not write it

out. Similarly, children recognize words that they could not write. The phenomenon suggests that there might not be a necessarily direct relationship between character recognition and writing.

Flores d' Arcais (1994) investigated the relationship between the pre-exposure of strokes and the reading of Chinese characters. Thirty-four undergraduate and graduate volunteers in Beijing were recruited to name characters with or without pre-exposure of one or two strokes of the followed character in four main conditions (no priming, random fragments, stroke writing order- early/ late, position- top left/ bottom right). The naming latency recorded in millisecond was employed as the dependent variable. The naming latency in the stroke writing order (early) condition was significantly smaller than that in other conditions. The results suggested that the first few strokes in the conventional stroke sequence of a character would facilitate the naming of the whole characters. The study addressed a number of issues but it did not address the effect of introducing stroke sequence on writing Chinese characters or the effect of the consistency of the stroke sequence introduced.

There was no study on the relationship between introducing stroke sequence and learning to write and on the relationship between the consistency of the introduced stroke sequence and learning to write. The present study aimed at investigate the following questions: (1) was there an effect of introducing stroke sequence on writing Chinese characters, and (2) was the consistency of the stroke sequences introduced a factor affecting the writing of Chinese characters.

Delay copying of pseudo-characters under different stroke sequence presentation conditions was employed in the present study. Since delay copying involves showing subjects the target character before requesting the subject to produce a written output, this procedure allows the manipulation of the stroke sequence presentation. Three stroke sequence conditions were used in the first part of the study: (1) Chinese characters were presented with conventional stroke sequence, (2) Chinese characters were presented with non-conventional stroke sequence, and (3) Chinese characters were presented as a whole without stroke sequence. In the second part of the study, there were two consistency conditions: (1) each Chinese character was presented twice with identical stroke sequence, and (2) each Chinese characters was presented twice with different stroke sequences. In the present study, the stimuli were carefully controlled on the number of strokes, the number of logographemes, the frequency of logographemes and all logographemes selected carry no phonological information. Pseudo-characters were used because it avoids activating of semantic representation which might become a confound factor. Logographemes used as the building block of pseudo-characters were controlled on the frequency of occurrence and the number of strokes. The performance in delay copying could then be used in answering the two questions mentioned above. The presence of effect from introducing stroke sequence on writing would be suggested by the significantly better performance in the presentation format with stroke sequence over the presentation format without stroke sequence.

The importance of introducing stroke sequence should be specified in the guide to curriculum then. When comparing performance in the consistency conditions, significantly better performance in the condition with characters presented twice with identical stroke sequence would suggest coordination within teachers and between schools and homes on the introduction of stroke sequence.

Method

Subjects

Four primary-one classes in a primary school were invited for screening of cognitive ability reading ability, visual spatial-relationship, visual memory and visual-motor coordination with five standardized tests - a nonverbal cognitive test named as Raven's Standard Progressive Matrices (Raven, 1986), a Chinese word reading test in the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho, & Chan, 2000), a visual spatial-relationship test and a visual memory test in Visual-perceptual Skills (non-motor) Revised (Gardner, 1996a), and a visual-motor test named as Test of Visual-motor Skills (Gardner, 1996b). They should have age appropriate abilities in the above five areas (Appendix B) to ensure all subjects have nonverbal cognitive ability reading ability, visual spatial-relationship, visual memory and visual-motor coordination within normal range.

A total of 36 primary-one students (18 males and 18 females) were recruited for experiment

1 and a total of another 32 primary-one students (16 males and 16 females) were recruited for experiment 2. All recruited subjects have normal nonverbal cognitive abilities (standard score above 90) and reading achievement of or above –1.67 standard deviation. The 36 subjects recruited for experiment 1 aged from 6;01 to 7;02 (mean age 6;07), with visual spatial-relationship of or above 53, visual memory of or above 21 and visual-motor coordination of or above 39. The 32 subjects recruited for experiment 2 aged from 6;02 to 7;09 (mean age 6;07), with visual spatial-relationship of or above 58, visual memory of or above 27 and visual-motor coordination of or above 21.

Stimuli

A total of 1383 different characters found in the Hong Kong Corpus of Primary School Characters (HKCPSC) (Leung, 2002) and in the primary-one textbooks were broken down into logographemes according to the rules adopted from Law et al. (2000). A total of 295 different logographemes in multi-stroke type, single-stroke type or combined type were identified. They were sorted according to their frequency of occurrence in ascending order. The first 98 logographemes (1st logographeme – 98th logographeme) were classified as low frequency, the followed 99 logographemes (99th logographeme - 197th logographeme) were classified as mid frequency, and the final 98 logographemes (198th logographeme – 295th logographeme) were classified as high frequency. Among the mid-frequency logographemes, 71 contained no

phonological information and 21 of them were used as the building block of the pseudo-characters used in this study. Pseudo-characters were used as stimuli in this study and were constructed from the mid-frequency logographemes without phonological representation arranged either horizontally ( ) or vertically ( ). The total number of strokes of each pseudo-character was controlled to between eight to ten strokes state.

Besides pseudo-characters, real characters were used to serve as fillers. High-frequency real characters to primary-one students according to the HKCPSC (Leung, 2002) were used. Each of them contained eight strokes and was made up of two logographemes.

Fifteen pseudo-characters and four real characters were used in experiment 1. Among the pseudo-characters, three of them contained logographemes arranged horizontally and twelve of them contained logographemes arranged vertically. There were three formats of presentation of each character: (1) the whole character was presented with conventional stroke sequence through playing a 10-second video clip (CSS); (2) the whole character was presented with non-conventional stroke sequence through playing a 10-second video clip (NSS); and (3) the whole character was presented without stroke sequence for 10 seconds (WC). In the CSS format, the conventional stroke sequence was adopted from Xie, Lu, & Wu (2001), Chen (1961) and Liu, Xia, Huang (1989). In the NSS format, the stroke sequence employed was non-conventional but was based on the stroke sequence rules (Appendix A). Eight pseudo-characters and three real

characters were used in experiment 2. Among the pseudo-characters, two of them contained logographemes arranged horizontally and six of them contained logographemes arranged vertically. There were two presentation formats: (1) the whole character was presented with stroke sequence which was non-conventional, through playing a 10-second video clip. (NSS1); (2) the whole character was presented with stroke sequence which was non-conventional and was different from NSS1, through playing a 10-second video clip. (NSS2). All of the non-conventional stroke sequences were based on the stroke sequence rules (Appendix A).

Procedures

In experiment 1, subjects were asked to do a delay copying task. In each trial, the target character was presented in one of the three formats (CSS, NSS or CS) followed by a digit memorization task which lasted for three seconds before writing down the target character within 13 seconds. There were 19 trials in total. The first two trials were demonstration trials where real characters were used. In the first trial, the character was presented in CSS format and answer was given immediately after the delay copying to enhance subjects' understanding of the procedures. In the second trial, the character was presented in WC format and answer was not given in this trial. The experiment trials were divided into three blocks. The first block of the task consisted of five pseudo-characters presented in one of the three formats. The second block of the task consisted of one real character filler at the beginning followed by five pseudo-characters

presented in one of the three formats. The last block of the task also consisted of one real character filler at the beginning followed by five pseudo-characters presented in one of the three formats. The whole task presentation was accomplished by playing a powerpoint file constructed for the experiment. To balance the order of the formats and the order of the stimuli, there were six different orders of the three presentation formats and two different orders of the stimuli (pseudo-character 1 to pseudo-character 15 or pseudo-character 15 to pseudo-character 1), resulting in a total of twelve groups (Appendix C).

In experiment 2, subjects were asked to do a delay copying task also and the stroke sequence used by the subjects in writing the characters was recorded using digital cameras with tripods. In each trial, the target character was presented twice in one of the two consistency conditions (consistent: NSS1-NSS1 or inconsistent: NSS1 -NSS2 or NSS2-NSS1) followed by a star counting tasks lasted for three seconds before writing down the target character within 13 seconds. There were 11 trials in total. The first two trials were demonstration trials where real characters were used. In the first trial, the character was presented in the consistent condition and answer was given immediately after the delay copying to enhance subjects' understanding of the procedures. In the second trial, the character was presented in the inconsistent condition without the provision of answer. The experiment trials were divided into two blocks. The first block of the task consisted of four pseudo-characters presented in either one of the conditions. The second

block of the task consisted of one real character filler at the beginning followed by four pseudo-characters presented in either one of the conditions. The whole task presentation was also accompanied by playing a powerpoint file constructed for the experiment. To balance the order of the conditions, the order of the stimuli and the order of formats in the inconsistent condition, there were two different orders of the conditions, two different orders of stimuli (pseudo-character 1 to pseudo-character 8 or pseudo-character 8 to pseudo-character 1) and two different orders of formats in the inconsistent condition (NSS1-NSS2 or NSS2-NSS1), resulting in a total of 8 groups (Appendix D).

After the delay copying task, subjects were interviewed with the use of a questionnaire about their view on stroke sequence (Appendix E).

Measurement

In experiment 1, the accuracy in delay copying was calculated separately according to the three presentation formats: (1) CSS; (2) NSS; and (3) WC. In experiment 2, the accuracy in delay copying was calculated separately according to the two consistency conditions: (1) consistent (NSS1-NSS1); and (2) inconsistent (NSS1-NSS2 or NSS2-NSS1). In the two experiments, one mark would be awarded for every correct logographeme in delay copying without the consideration of stroke sequence being used. That was, a correct character would yield a total of

two marks. The accuracy in writing fillers and real characters in the demonstration trials was disregarded in calculating the accuracy in delay copying.

As there was recording on the stroke sequence used by the subjects in experiment 2, the used stroke sequence was analyzed separately according to the two consistency conditions: (1) consistent; and (2) inconsistent. The smallest unit to be analyzed was logographeme and only the correctly written logographemes were categorized according to the criteria listed in table 1. The percentage of logographemes in each category of different conditions was calculated.

Table 1. *Categorization criteria across different stroke sequence used by subjects*

Category implicated	Criteria
Conventional stroke sequence (conv)	Logographemes were written in conventional stroke sequence.
Consistent stroke sequence (cons)	Logographemes were written in the stroke sequence consistent to the one presented in video.
Self-developed stroke sequence (self)	Logographemes were written in stroke sequence other than the conventional one and the presented one.
Others	Logographemes were written with reversal of stroke (the stroke was being written along a reversed direction) or with broken stroke (one stroke was written as two or more strokes).

Research design

For the two experiments, both involved only one independent variable. In experiment 1, the dependent variable was the accuracy in delay copying and the independent variable was the presentation formats of characters: (1) CSS; (2) NSS; and (3) WC. In experiment 2, the dependent variable was also the accuracy in delay copying and the independent variable was the consistency of stroke sequence in presenting characters: (1) consistent; and (2) inconsistent. Two separated repeated group analysis of variance was used to identify the effect of stroke sequence and consistency.

Results

Quantitative analysis

The data in experiment 1 were analyzed statistically using single factor, repeated group analysis of variance. The null hypothesis could not be rejected, $F(2,70) = 0.7326$, $p = 0.4843$ (> 0.05). Post-hoc comparison (Tukey HSD test) was carried out and there was no significant main effect (table 2). Subjects did not perform significantly better in any of the presentation formats and the performance in the three formats were similar.

Table 2. *Result of post-hoc comparison (Tukey HSD test) in experiment 1*

Presentation format (level of independent variable)	CSS	NSS	WC
CSS		0.499279 (>0.05)	0.616193 (>0.05)
NSS	0.499279 (>0.05)		0.980730 (>0.05)
WC	0.616193 (>0.05)	0.980730 (>0.05)	

The data in experiment 2 were analyzed statistically using single factor, repeated group analysis of variance. The null hypothesis could not be rejected, $F(1,31) = 0.0096$, $p = 0.9226$ (> 0.05). Subjects did not perform significantly better in neither one of the consistency conditions and the performance in the two conditions was similar.

Questionnaires were distributed to the subjects for filling in after the delay copying. There were 68 respondents. Most of them reported that they had learnt stroke sequence rules (91.2% of respondents), believed that stroke sequence was important (92.6% of respondents) and claimed that they would follow stroke sequence rules in writing (91.2% of respondents). They mainly learnt the stroke sequence rules from teachers (52.5%), parents (36.6%), the principle (6.9%) and classmates (6.9%).

Qualitative analysis

Nineteen subjects in experiment 2 were successfully recorded during the delay copying.

There were 63 correctly written logographemes in the consistent condition and 52 correctly written logographemes in the inconsistent condition in total. They were analyzed with the result presented in figure 1.

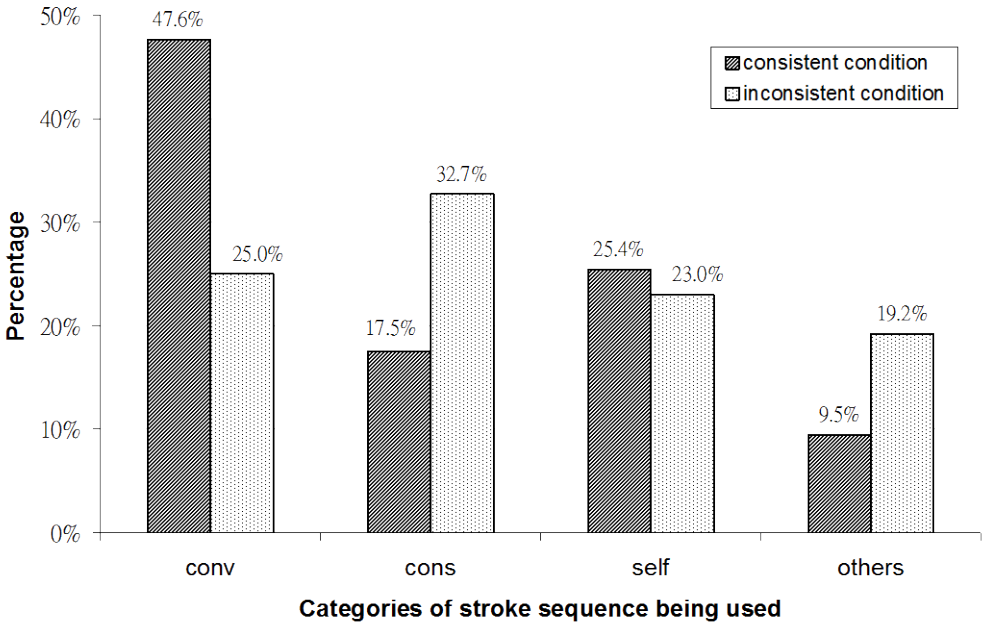

Figure 1. *The distribution of stroke sequence being used in experiment 2*

Conventional-stroke-sequence group occupied the greatest percentage in the consistent condition while consistent-stroke-sequence group occupied the greatest percentage in the inconsistent group. It suggested that the stroke sequence introduced did affect writing. But the effect was on the use of stroke sequence but not writing accuracy.

Discussion

The present study verified the myth of the benefit from introducing stroke sequence on

writing Chinese characters through investigating the effect of introducing stroke sequence and the effect of stroke sequence consistency on delay copying. In the present study, whole character was given together with or without stroke sequence. The similar performance in the three presentation formats shown in experiment 1 suggested that there was little or no effect from the additional introduction of stroke sequence on writing accuracy. The myth was not supported with the findings in the present study. The similar performance in the two consistency conditions shown in experiment 2 suggested that there was little or no effect from the consistency of the introduced stroke sequence on writing accuracy. The possible disagreement between schools and families on stroke sequence would not result in adverse effect on children in writing correctly.

The finding in the present study was contradictory to the facilitative effect suggested from the stroke sequence and spatial information embedded in the passive finger tracing in Yim-Ng et al.'s study (2000) and from the pre-exposure of the first few strokes in the conventional stroke sequence in Flores d' Arcais's study (1994) on character recognition. The main difference between the two studies and the present study was that the former two were investigating character recognition and the latter one was investigating character writing. There might be different processes involved in character recognition and writing on utilizing the information from stroke sequence and spatial arrangement. It was known that visual presentation of words could automatically activate the semantic representation directly or through the access of

phonological representation. (Gentilucci, & Gangitano, 1998; Posner, Petersen, Fox, & Raichle, 1988). A sensorimotor representation, including the motor program for writing and the associated kinesthetic feedback gradually links to the corresponding visual representation through practice, resulting in a multi-modal representation (Longcamp, Anton, Roth, & Velay, 2003). Motor schema which contains the information about stroke sequence could be used as an access code in activating other representations of a character in the multi-modal representation. Each representation and each link between representations develop separately through learning and mapping. By using the multi-modal representation, the phenomenon of being able to recognizing words but not write could be explained because writing involves both central and peripheral processes, where output modalities are integrated in the central process (Moretti, Torre, Antonello, Fabbro, Cazzato, & Bava, 2003). It is possible for people to recognize words by giving either their meaning or their pronunciation but not being able to write them out.

Although there was no enhancement on writing accuracy from the stroke sequence and the spatial information, there was effect on the stroke sequence being used in writing. In the consistent condition, most logographemes were written in conventional stroke sequence. In the inconsistent condition, most logographemes were written in stroke sequence consistent to the presented one in video. There was a change of distribution on the stroke sequence being used in the two consistency conditions. The use of stroke sequence when consistent stroke sequence was

introduced was different from that when inconsistent stroke sequence was introduced. It reflected that the introduced stroke sequence did affect the sequence employed in writing. The phenomenon found in the present study tallied with the description in Law et al.'s study (1998) that primary-one students in Hong Kong could write accurately in non-conventional stroke sequence. Although it was common to find subjects in the present study to write characters in non-conventional stroke sequence, most of them did learn stroke sequence rules mainly from teachers and parents. They also believed that stroke sequence was important and claimed that they would follow stroke sequence rules in writing. Law et al. suggested that primary-one students might have insufficient ability in online controlling and adjusting the sequential motor execution according to this phenomenon. As it was showed in the present study that there was no benefit from the additional stroke sequence on writing accuracy, there might be purpose other than improving writing accuracy in introducing stroke sequence and teaching stroke sequence rules. One Chinese teacher in the primary school was invited to give comment on this issue and it was reported that the use of introducing stroke sequence and teaching stroke sequences rules served in, for example, counting number of strokes in a character for correct search in a dictionary, neatness and tidiness in writing.

As children studying primary one wrote in the conventional stroke sequence in much more occasions when consistent stroke sequence was introduced, attention should be paid on the

manipulation of consistency of the stroke sequence introduced for consolidating the use of conventional stroke sequence in writing. The Curriculum Development Council of the Education Department could give more guidelines on stroke sequence such as the time when stroke sequence is introduced and the order of sequence rules being taught and could specify the expected goal for introducing stroke sequence and teaching stroke sequence rules to both pre-primary settings and primary schools. Normally, the introduction of conventional stroke sequence and the teaching of stroke sequence rules are finished before the second semester of primary one. The time interval of manipulating the consistency on the introduced stroke sequence could not be suggested from the present study as only primary-one students were recruited as subjects and they were only investigated on writing at a point of time. Further study could be done on children in other grades or at different time in an academic year in order to check whether there is a change on the use of stroke sequence along the development.

References

Chen, M.J. (1996) An overview of the characteristics of the Chinese writing system. *Asia Pacific Journal of Speech, Language and Hearing, 1*, 43-54.

Fei, J. (1992). *Han zi xie fa gui fan zi dian[漢字寫法規範字典]*. Shanghai: Shanghai ci shu.

Flores d' Arcais, G.B. (1994). Order of strokes writing as a cue for retrieval in reading Chinese characters. *European Journal of Cognitive Psychology, 6(4),* 337-355.

Gardner, M.F. (1996a). *Test of Visual-perceptual Skills (non-motor) Revised*. Hydesville: Psychological and Educational Publication.

Gardner, M.F. (1996b). *Test of Visual-motor Skills Revised.* Burlingame: Psychological and Educational Publication.

Gentilucci, M., & Gangitano, M. (1998). Short communication: Influence of automatic word reading on motor control.

Ho, C.S.H., & Chan , D.W.O. (2000). *The Hong Kong test of Specific Learning Difficulties in Reading and Writing.* Hong Kong: Education Department, HKSAR Government.

Law, N., Ki, W.W., Chung, A.L.S, Ko, P.Y., & Lam, H.C. (1998). Children's stroke sequence errors in writing Chinese characters. *Reading and Writing: An Interdisciplinary Journal, 10,* 267-292.

Law, S.-P., & Leung, M.-T. (2000). Structural representation of characters in Chinese writing: Evidence from a case of acquired dysgraphia. *Psychologia, 43,* 67-83.

Leung, M.-T. (2002). Hong Kong Corpus of Primary School Characters (HKCPSC). Hong Kong: the University of Hong Kong.

Liu, N., Xia, Y., & Huang, D. (1989). *Xianggang xiao xue sheng zhong wen ci dian [香港小學生中文詞典]*. Hong Kong: Ming hua chu ban gong si.

Longcamp, M., Anton, J.-L., Roth, M., & Velay, J.-L. (2003). Visual representation of single letters activates a premotor area involved in writing. *NeuroImage, 19,* 1492-1500.

Moretti, R., Torre, P., Antonello, R.M., Fabbro, F., Cazzato, G., & Bava, A. (2003). Writing errors by normal subjects. *Perceptual and Motor Skills, 97,* 215-229.

Posner, M.I., Petersen, S.E., Fox, P.T., & Raichle, M.E. (1988). Localization of cognitive operations in human brain. *Science, 240,* 1627-1631.

Raven, J.C. (1986). *Hong Kong Supplement to Guide to the Standard Progressive Matrices.* Hong Kong: Education Department, HKSAR Government.

Wang, W.S.Y. (1973). The Chinese Language. *Scientific American, 228,* 50-60.

Xie, L., Lu, J. & Wu, Q. (2001). *Biao zhun guo yu bi shun ci dian [標準國語筆順辭典]*. Taiwan : Jian li shu ju

Yim-Ng, Y.-Y., Varley, R., & Andrade, J. (2000). Contribution of finger tracing to the recognition of Chinese characters. *International Journal of Language and Communication Disorders, 35(4),* 561-571.

Appendixes

Appendix A

Table 3. *Major stroke sequence rules for Kai Shu (Fei, 1992)*

1	Writing a horizontal stroke before a vertical stroke (先橫後直), e.g. 十, 聿
2	Writing a downward stroke going to the left before a downward stroke going to the right (先撇後捺), e.g. 人, 文
3	Writing from top to bottom (從上到下), e.g. 三, 言
4	Writing from left to right (從左到右), e.g. 仁, 杉
5	Writing from outside to inside (先外後內), e.g. 問, 風
6	Writing from outside to inside before the last horizontal stroke (先外後內再封口), e.g. 田, 國
7	Writing center stroke before symmetrical wings (先中間後兩邊), e.g. 小, 水

Table 4. *The supplementary stroke sequence rules for Kai Shu (Fei, 1992)*

1	Writing dots that are at the top or the left upper corner at first (點在上邊或左上先寫), e.g. 衣, 沐
2	Writing dots that are at the right upper corner or inside other strokes at last (點在右上或字裏後寫), e.g. 尤, 叉
3	Writing enclosing parts that are at the left upper corner or the right upper corner at first (左上和右上的包圍結構先外後內), e.g. 厭, 司
4	Writing enclosing parts that are at the left bottom at last (左下的包圍結構先內後外), e.g. 這, 建
5	Writing enclosing parts from three sides that the opening facing the top at last (三面包圍結構缺口朝上的先內後外), e.g. 凶
6	Writing enclosing parts from three sides that the opening facing the bottom at first (三面結構缺口朝下的先外後內), e.g. 同
7	Writing the upper stroke of the enclosing parts from three sides that the opening facing the right at first and the other strokes of the enclosing parts at last (三面結構缺口朝右的先上後內再左下), e.g. 區

Appendix B

Table 5. *The inclusion criteria on the performance in screening*

Ability to be screened	Assessment tools	Inclusion range (normal range)
Nonverbal cognitive ability	Raven's Standard Progressive Matrices (Raven, 1986)	Standard score >90
Reading ability	The Chinese word reading test in the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho, & Chan, 2000)	Achievement > -2 standard deviation
Visual spatial-relationship	The visual spatial-relationship test in Visual-perceptual Skills (non-motor) Revised (Gardner, 1996)	Percentile > 10
Visual memory	The visual memory test in Visual-perceptual Skills (non-motor) Revised (Gardner, 1996)	Percentile > 10
Visual-motor coordination	Test of Visual-motor Skills (Gardner, 1996)	Percentile > 10

Appendix C

Table 6. *The order of the three presentation formats and the stimuli in experiment 1*

Group name	Pseudo-character order	Format in the first block	Format in the second block	Format in the third block
A1	1→15	CSS	NSS	WC
A2	15→1	CSS	NSS	WC
A3	1→15	CSS	WC	NSS
A4	15→1	CSS	WC	NSS
A5	1→15	NSS	CSS	WC
A6	15→1	NSS	CSS	WC
A7	1→15	NSS	WC	CSS
A8	15→1	NSS	WC	CSS
A9	1→15	WC	CSS	NSS
A10	15→1	WC	CSS	NSS
A11	1→15	WC	NSS	CSS
A12	15→1	WC	NSS	CSS

Appendix D

Table 7. *The order of the two presentation conditions, the stimuli and the presentation formats in the inconsistent condition in experiment 2*

Group name	Pseudo-character order	Format order in the inconsistent condition	Condition in the first block	Condition in the second block
B1a	1→8	NSS1-NSS2	Consistent	Inconsistent
B1b	1→8	NSS2-NSS1	Consistent	Inconsistent
B2a	8→1	NSS1-NSS2	Consistent	Inconsistent
B2b	8→1	NSS2-NSS1	Consistent	Inconsistent
B3a	1→8	NSS1-NSS2	Inconsistent	Consistent
B3b	1→8	NSS2-NSS1	Inconsistent	Consistent
B4a	8→1	NSS1-NSS2	Inconsistent	Consistent
B4b	8→1	NSS2-NSS1	Inconsistent	Consistent

Appendix E

The questionnaire given to subjects for filling in after the delay copying task

姓名: _____ 班別: _____ ( )

問卷調查

1. 有沒有學過筆順規則?
請圈 " ◯ " (圈一個)

有 ✓　　沒有 X

2. 從哪兒學筆順規則?
請圈 " ◯ " (可多過一個)


老師


父母


同學

其他 ?

誰: _____

3. 你覺得筆順重要嗎?
請圈 " ◯ " (圈一個)

重要 ✓　　不重要 X

4. 你寫字時有沒有遵守筆順規則?
請圈 " ◯ " (圈一個)

有 ✓　　沒有 X